Rotating frame relaxation imaging of prostate cancer: a feasibility study
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Introduction
Rotating frame relaxations, $T_{RAFF}$ and relaxation along fictitious field (RAFF) (1) have shown to be promising markers for several pathologies including cancer. We aimed to investigate the feasibility of RAFF and continuous wave $T_{1\rho}$ imaging of prostate cancer (PCa) at 3 Tesla (T).

Methods
Twenty-seven patients (mean age 63 ± 7 years) with histologically confirmed PCa underwent two repeated 3T MRI (Philips, Ingenuity PET/MR) examinations using 32 channel surface array coil and 2 channel volume whole body RF coil for RF transmission before radical prostatectomy. After the first examination, a patient was taken out of the MRI bore and asked to rest for several minutes. After re-positioning of the patient on the MRI table, the second MRI examination was performed. Both, $T_{RAFF}$ and $T_{1\rho}$ were measured using 3D $T_1\text{FFE}$ sequence (TR/TE 3.2/1.5 ms; FOV: 375x375 mm$^2$; matrix size 150 x 150) with centric coding and 500 Hz RF peak amplitude. The pulse train duration for RAFF was 0, 45, and 90 ms while 0, 20 ms, and 80 ms were applied for continuous wave $T_{1\rho}$. $T_2$ was measured using TR/TEs of 686/20, 40, 80,100 ms; FOV 230x183 mm$^2$, matrix size 256 x 162. $T_2$ mapping was performed only during the first examination. $B_1$ was mapped using AFI method (2). Using whole mount prostatectomy sections as reference, ROIs ($T_{RAFF}$ and $T_{1\rho}$: 5.85x5.85 mm$^2$, $T_2$:5.39x5.39 mm$^2$) were placed in the areas of PCa, normal peripheral zone (PZ) and normal central zone (CZ). $T_{RAFF}$, $T_{1\rho}$ and $T_2$ values were calculated by fitting mono-exponential function to RAFF, $T_{1\rho}$ and $T_2$ weighted data. Means of two measurements for $T_{RAFF}$, $T_{1\rho}$, and individual $T_2$ values were compared using ANOVA with Bonferroni multiple comparisons test. In order to assess repeatability of the $T_{RAFF}$ and $T_{1\rho}$ measurements, the difference between two measurements (d), mean squared difference (MSD), 95% confidence interval (CI) for changes of the quantitative values of all patients (n) in the study cohort and the coefficient of repeatability (CV) were calculated.

Results
Both $T_{RAFF}$ and $T_{1\rho}$ mappings were successful (Figure 1) in all 27 patients with reasonably homogenous $B_1$ field across prostate. Mean $T_{RAFF}$ value of PCa was 128 ± 14 ms, differed significantly (p<0.05) from similar value of normal PZ (174 ± 21 ms) and normal CZ (141±12 ms). Significant difference between mean $T_{1\rho}$ values of PCa (77±12 ms) and normal PZ (103 ± 19 ms) was present while the difference between PCa and normal CZ (85 ± 10 ms) did not reach statistical significance. Mean $T_2$ values of PCa, normal PZ and normal CZ were 78 ± 11 ms, 119± 22 ms and 91 ± 31 ms, respectively (Figure 2). CI and CV are summarized in Table 1.

Conclusions
Rotating frame imaging (RAFF, and continuous wave $T_{1\rho}$) of PCa was feasible using clinical 3T MRI scanner and demonstrated robust repeatability. Both $T_{RAFF}$ and $T_{1\rho}$ of PCa differed significantly from similar value of normal PZ. RAFF method demonstrated improved image quality compared to block pulse which together with smaller specific absorption rate (39%) compared to continuous wave pulse makes RAFF an attractive method for PCa imaging. Further studies are needed to establish the role of rotating frame imaging as a part of multiparametric prostate MRI.